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(54) "MOULDING APPARATUS"

(71) We, HANFORD BOOT RESEARCH PTY. LTD., a company duly incorporated under the laws of the State of New South Wales, Commonwealth of Australia, of 17 Bridge Street, Pymble, New South Wales, Commonwealth of Australia, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to improvements in moulding and the dewatering of slurries particularly but not exclusively for moulding purposes and in particular the dewatering of concrete type slurries. While the dewatering of slurries is not new, the dewatering of concrete type slurries has not been exploited to a great degree.

The purpose of dewatering for moulding purposes is to remove the excess water or fluid used temporarily as a conductor or conveyor of the material to be moulded so as to minimise the difficulties of the moulding procedure. Concrete, for instance, needs "free" water to lubricate and transport the various particles that make up the mix design. Water, however, being the chemical "partner" for cement has a diluting effect on the strength of the cement binder, i.e., the more water that is used in concrete mix design, the weaker the strength of that design. In addition to a reduction in strength, there is also a marked increase in drying shrinkage of the moulded component where excess water is used.

To achieve good surface finish (for which water is also needed to release entrapped air against the mould surface) a proven method is to put the water into the mix and when moulded to dewater or extract the excess water by pressing or vacuuming or both, the excess water being forced to pass through a membrane of some kind that permits the water to pass through while holding back the solids forming the slurry.

In making a restrained moulded product, such as a concrete box or thin walled concrete cell intended to form a room module of a house shrinkage is most important as each panel forming a side of the box or cell is restrained at its perimeter, thus any excess shrinkage will cause stress concentrations and visible cracking, thus weakening the structure.

In making such a thin walled structure the very fact of having to cast sections that are thin precludes the use of larger diameter aggregates, again compounding the problem, for the smaller the particle sizes, then the more "free" water required to lubricate them to make them mobile.

Where it is required to pump or inject the mould with a concrete slurry there has to be a substantial amount of both fine particles and free water in order to control segregation due to pump pressures. Various types of chemicals and admixtures are available to both reduce water content and prevent segregation and much is known about the performances of these admixtures. However, as stated above there is no better or cheaper conveyor of entrapped air within the mould than water. It is thus desirable to include enough water in the mix design to allow both low pump pressures in injecting and good surface finish and then to extract the water when the mould is adequately filled.

However, cement particles and indeed some fine sand particles are extremely small in size, some cement particles can range in size from less than 0.5 to 5 microns, thus allowing these particles to either block, clog or pass through even the smallest of holes, making cleaning of the dewatering membrane a difficult and costly process, especially if the cement is allowed to set.

In dewatering concretes and slurries in a mould to achieve good compactability the mould faces have to "take up" the volume of the extracted water so that pressure is needed to force the two surfaces of the mould together if a good surface finish is required. Vibration also can assist in attaining this goal.

However, in attaining a mould surface that not only has to sustain hydrostatic pressures but also vibration and physical pressing pres-

sures, the mould surfaces must be quite strong. This precludes having as part of the mould membrane very small holes, as it is very difficult to manufacture holes of the size of 0.005" in a steel or metal sheet that will withstand the pressures involved and if such holes can be produced, they are subjected to blockage because of the irregular shaped particles passing through them. When this happens the holes cease to dewater the moulded material and cleaning the holes can be very difficult and expensive.

The criteria for a satisfactory dewatering membrane are that:

a) it will not allow an excessive amount of slurry particles through,

b) it must allow water through at the desired rate,

c) it must be capable of being easily cleaned,

d) it must be strong enough to withstand the required pressures,

e) it must not become blocked during dewatering or clogged,

f) if the dewatering membrane is on the upper surface of the moulded product, then the membrane must not allow the separated water to flow back onto the product when stripping takes place; this usually occurs because of the suction of the membrane to the moulded product, thereby sucking the water back through the membrane and ruining the surface of the just moulded product,

g) it should not strip too many of the fine particles from the dewatered surface, thus leaving it sandy in texture and weak.

Apart from the criteria that are listed above, a further criterion arises from the fact that the most important part of dewatering a pumped or injected moulded product is to make sure that the integrity or fluidity of the slurry is maintained adequately until the mould is full otherwise the slurry "dries out" during injection and either gives a poor product or in some circumstances the mould cannot be properly filled as the material solidifies prematurely or progressively during injection.

In moulding large products such as a thin-walled concrete room sized module, this problem is possibly the biggest one to overcome. If in order to maintain fluidity of the slurry the pumping or injecting procedure is speeded up and the pressures are elevated due to the friction of the slurry and the surfaces against which it is moving, this, unfortunately, speeds up the rate of dewatering, as water will pass through even the smallest of apertures at a surprising rate when even under very slight pressure and increases as the pressure increases.

Merely increasing the amount of free water in the slurry cannot compensate quickly enough for the loss and an excess of water can cause segregation of the particles when under pressure. Also the first amount of slurry into the mould is the first subject to water loss so that the slurry itself changes its characteristics, preventing acceptable mouldings from being produced.

To mould such a concrete module upwards of 50 cu. ft. of slurry has to be injected into the mould (the moulding process will normally preclude it from being poured in a conventional manner), and under the circumstances the problem of water loss during injection became the most critical problem.

In attempting to solve this problem it became apparent that what was needed was a "pressure sensitive dewatering membrane" i.e. one that could be controlled so that it would substantially not dewater at certain pressures and yet still dewater when the pressures within the mould reached a prescribed level, and one that would not let excessive amounts of fine particles through with the water.

In an attempt to put this idea into practice one method used was to inflate an air bag behind the holes in a membrane until the mould was full, then deflate the bag and allow dewatering. This did not work, however, as the fine particles that this particular membrane allowed through packed within the fine holes and thus effectively blocked them, preventing dewatering at all.

After trying different materials a solution to the problem was finally arrived at.

The present invention thus consists in a moulding apparatus for moulding a thin-walled concrete room-sized module comprising a mould having a mould cavity for forming said module, conduit means for introducing a concrete slurry into the mould cavity, a sheet of flexible elastomeric pressure sensitive dewatering membrane extending over a major part of the area of said mould cavity, a plurality of normally closed slit means arranged at intervals over said sheet and extending from one face of the sheet to the opposite face, said slit means opening only on the application of a pressure difference across said sheet of at least a predetermined magnitude to pass water in the concrete slurry out of the mould cavity through said sheet at a significant rate while preventing the passage of substantial amounts of concrete particles in said slurry through said sheet.

In order that the nature of the invention may be better understood a preferred form thereof is hereinafter described, by way of example, with reference to the accompanying diagrammatic drawings in which:-

Figure 1 is a perspective view of a part of a mould incorporating the present invention,

Figure 2 is a plan view of a rubber sheet forming part of said apparatus,

Figure 2a is a typical section through the sheet of Figure 2,

Figure 3 is a perspective view of an alternative form of apparatus,

Figure 4 is a plan view of an area of the apparatus of Figure 3 and,

Figure 5a and 5b are sectional views through two types of rubber insert used in the apparatus of Figure 4.

The apparatus illustrated in Figures 1, 2 and

2a consists of

1. A mould having a mould element 10 closing one face of the mould the whole face constituting an aperture in the mould and sufficiently rigid to withstand 40 pounds per square inch without deflection, being made of steel and being substantially flat. It is moveable under pressure applied by press C in the direction of the opposite face 11 of the mould to apply pressure to the slurry therein.

2. A woven steel mesh 12 approximately ¼" x ¼" x 1/8" diameter and being able to withstand the 40 p.s.i. mentioned above.

3. A natural gum rubber sheet 13 of between 70 and 100 thousandths of an inch thick having a hardness of between 30 and 40 Durometer Shore hardness. In the rubber sheet slits in the form of crosses 14 are cut which measure ¼" x ¼" and which are spaced ½" apart centre to centre, these slits constituting the valve means.

The woven mesh 12 is fixed or laid onto the mould element 10 and the rubber sheet 13 is laid against the woven mesh 12 and attached by gluing at its perimeter.

Natural rubber is to be preferred in that immediately after cutting cruciform slits 14 comprising a pair of linear slits at right angles intersecting at their mid-points into it the excellent memory characteristics of natural gum rubber make themselves apparent, by returning the rubber to its original state and closing the slits 14 up again, leaving no visible gap in the sheet, as no material is taken out of the rubber sheet when making the slits 14. In place of cruciform slits simple linear slits or slits of curved configuration may be used.

When injection or casting is commenced from pump A the rubber sheet 13 is in a relaxed state, i.e., the slits 14 are closed. As the pressure is increased the rubber sheet is pressed against the woven mesh 12 and is made to stretch. This in turn has the effect of opening the slits 14, when the pressure reaches a predetermined magnitude and allowing the slurry which is being moulded to be effectively dewatered.

The variables to be taken into account in order to "tailor make" apparatus of the kind illustrated to suit the moulding application are:

1. The pressure applied to the mould.

2. The amount and shape of the deformation of the deformed steel mesh, i.e., the slope could give low initial deflection and then change to a higher deflection due to its contours.

3. The pressure generated during the injection or moulding procedure.

4. The thickness and hardness of the rubber sheeting and its reaction to the deformed steel mesh. Generally speaking the amount of slits open for a given pressure depends on the thickness of the sheet and thus with increased pressure the thickness of the sheet may be increased for the same degree of opening.

5. The size, shape and configuration of the slits cut into the rubber sheet.

6. The spacing apart of the above-mentioned slits cut into the rubber sheet; these must not be too closely spaced as otherwise the strength of the sheet is reduced and thus its power to reclose the slits when pressure is removed. In general the spacing between the slits or other valve means is small in relation to the area of the sheet or other member in contact with the slurry.

7. The method of laying the rubber sheet onto the woven steel mesh, is such that it can be stretched to slightly open the slits or it can be very loose thus requiring more deformation before allowing the water to pass through it.

An advantage of the type of apparatus described is that it is superior to other types if a pressure adjusting or balancing technique is required, e.g., if a fluid or air pressure were applied to the dewatering chamber at the back of the sheet, i.e., the woven steel mesh side through the pipe B, then the "life" of the material to be dewatered could be prolonged. The approximate balancing of the pressures on either side of the rubber sheet would have the effect of not allowing the rubber sheet to become deformed or stretched, thus keeping the slits in a relatively closed position, allowing closer control of the process of moulding.

There are several methods of achieving this. One is to flood the complete two chambers with fluid, i.e., either side of the sheet, prior to injection. When injection is commenced the injected slurry displaces the fluid as it fills the moulding chamber and the excess fluid is allowed to be pushed out of the moulding chamber. The subsequent effect is that the hydrostatic pressure of the injected material is substantially balanced by the hydrostatic pressure of the fluid still occupying the dewatering chamber and indeed during injection this occurs automatically.

Another method is to allow a fluid, introduced into the dewatering chamber to match the progress of the moulding slurry as it travels up the mould, thus automatically substantially balancing the pressures in the two chambers during and after injection until it is desired to effect dewatering of the slurry.

Another method is to balance the pressure with air pressure placed into a part of the dewatering chamber as soon as the injected slurry has filled that portion of the mould where the pressure compensation or balancing is required.

An advantageous feature of the apparatus described is that during stripping of the moulded product, the slits in the sheet are closed, thus preventing any water from escaping back through the sheet and ruining the newly moulded product. This is especially important where the sheet is situated on the upper side of the mould, i.e., in a substantially horizontal position. During stripping, suction on the moulded product is reduced. As pressure on the sheet is reduced it is caused to return to its orig-

inal configuration and a creeping action takes place breaking the seal between the product and the membrane.

Apparatus such as that described is easy to clean, as it is flexible and binders similar in type to cement, cannot permanently adhere to it; the fact that it is continually being stretched and then returned is sufficient to break up any bonding that may have occurred. The sheet can be cleaned from either side, preferably, however, from the moulding side with a water pressure cleaner, the pressure again stretching the material, opening the slits or crosses and washing out any sediment that may have been caught in them.

It has been found that the water that is extracted from the moulded product is relatively clean with the type of rubber sheet described because the size of the slits can be closely controlled by changing the variables listed above. For instance, a thicker rubber will allow less sediment through than a thinner rubber but will also tend to dewater in a slower time depending on the design and contours of the deformed steel mesh.

Another advantage of this type of sheet is that if other than pressing alone is required for dewatering, then vacuuming facilities through pipe B can be added to the dewatering chamber. This permits dewatering to be effected at a greater rate.

While the form of construction described above is to be preferred the apparatus may take a variety of other forms. The woven steel mesh for example may be replaced by any other member that has the effect of supporting the rubber sheet while allowing the slits in it to open and also allowing water extracted from the slurry to escape.

In the modified form of construction shown in Figure 3 a perforated steel plate 15 is used having a series of perforations 16 formed in it and arranged evenly over its surface.

The valves are provided as shown in Figure 5a, by means of a rubber sheet 17 that overlies the plate 15. The sheet 17 has moulded into its surface a series of convex or domed projections 18, in each of which a cruciform slit 19 is cut to penetrate the material, The sheet 17 is formed either with or without tubular projections 20 that enter the perforations 16. By reason of the provision of the convex projection 18 when the sheet is deformed under pressure to open the slits 19 it presents a substantially flat surface to the slurry being moulded.

In an alternative arrangement shown in Figure 5a the rubber sheet 17 may be replaced by a number of discrete rubber or other resiliently flexible elements 21 having in them cruciform slits 22 each fitting like a grommet in one of the perforations 16.

From the above it will be appreciated that it is not necessary that the support material for the rubber has to be deformed although at this state it would appear to be easier and more economical. However, the advantage of having a pre-deformed rubber sheet such as 17 is that when moulding materials for dewatering the finished mould is substantially flat whereas in the first instance where the rubber deforms during moulding the finished moulded dewatered article has a rough or deformed surface.

If a domed button or sheet is used the slits can either be cut or moulded into the top of the dome. The action when the moulding chamber is full and under pressure is to put the dome into compression, thus closing the slits more tightly. When the pressure reaches a prescribed level, then the dome will collapse and open, thus allowing it to deflect into the underlying hole of the plate 15. This opens the slits and allows dewatering to take place.

In both examples of member it is not necessary that additional pressure be applied to the mould surfaces to cause deformation of the rubber sheeting, e.g., a vacuum could be applied to the dewatering chamber thus deforming the rubber or causing deflections in the sheet and allow dewatering. It can be seen that in this way the invention lends itself to a great range of dewatering applications.

In general, application of a pressure either in the moulding chamber or a negative pressure in the dewatering chamber causes a deformation or a change in the surface area of a flexible dewatering sheet allowing slits of various types and configurations to open and allow the moulded material to be effectively dewatered. Its action is adjustable to suit virtually any requirements or specifications where two chambers have a differential pressure in them.

Experiments have shown that vibration can cause agitation of the slits and so speed up the dewatering process. The vibration also affects the particles of the moulded material as well as the free water in the material.

It should be pointed out that the material used for the flexible lining with the slits cut into it should have good memory characteristics, i.e., it should return easily to its manufactured shape. This factor is thought to be important for long life, easy cleaning and to "seal off" the member from the moulded product immediately on stripping. While natural rubber has been found to be the most satisfactory material for this purpose other plastic or elastomeric materials with the desired characteristics may be used.

WHAT WE CLAIM IS:-

1. Moulding apparatus for moulding a thin-walled concrete room-sized module comprising a mould having a mould cavity for forming said module, conduit means for introducing a concrete slurry into the mould cavity, a sheet of flexible elastomeric pressure sensitive dewatering membrane extending over a major part of the area of said mould cavity, a plurality of normally closed slit means arranged at intervals over said sheet and extending from one face of the sheet to the opposite face, said

slit means opening only on the application of a pressure difference across said sheet of at least a predetermined magnitude to pass water in the concrete slurry out of the mould cavity through said sheet at a significant rate while preventing the passage of substantial amounts of concrete particles in said slurry through said sheet.

2. Apparatus as claimed in Claim 1, wherein said elastomeric material is natural gum rubber.

3. Apparatus as claimed in Claim 2, wherein said natural rubber has a thickness of between 70 and 100 thousandths of an inch and a Durometer Shore hardness of between 30 and 40.

4. Apparatus as claimed in any one of the preceding claims, wherein said slits are cruciform.

5. Apparatus as claimed in Claim 4, wherein said cruciform slits are composed of linear slits arranged at right angles and intersecting at their mid points.

6. Apparatus as claimed in any one of the preceding claims, wherein the means supporting said sheet is a woven mesh material.

7. Apparatus as claimed in any one of the preceding claims, wherein means are provided for applying pressure to said mould cavity defining means to increase the pressure of said concrete slurry.

8. Moulding apparatus for moulding a thin-walled concrete room-sized module substantially as described and as shown in the accompanying drawings.

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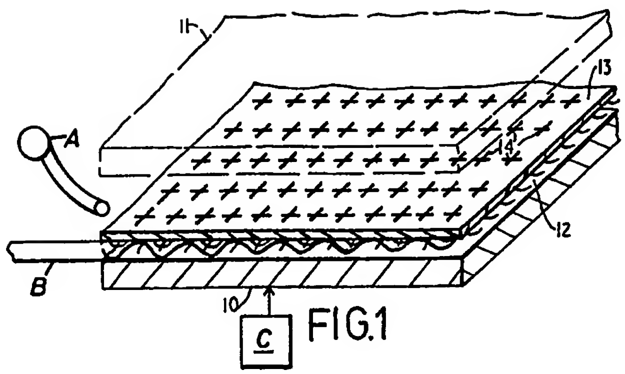

FIG.1

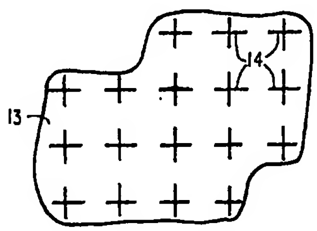

FIG.2

FIG.2a

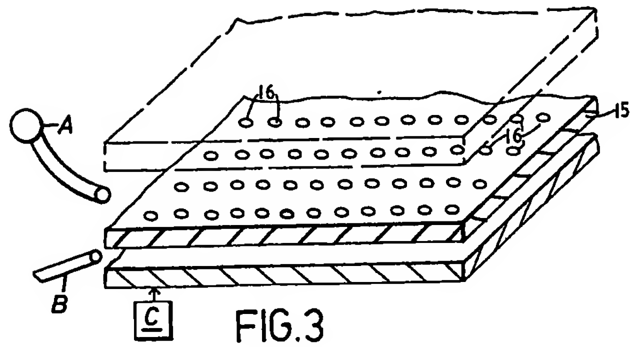

FIG.3

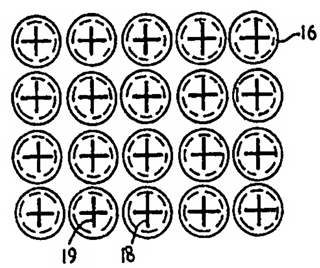

FIG.4

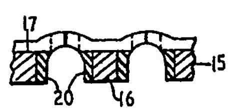

FIG.5a

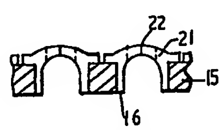

FIG.5b